Fire and haze in Indonesia: causes, impacts and predictability

Robert Field

Shawki, D., R.D. Field, M.K. Tippett, B.H. Saharjo, I. Albar, D. Atmoko, A. Voulgarakis, Long-lead prediction of the 2015 fire and haze episode in Indonesia, Geophysical Research Letters, 44, 9996–10,005, https://doi.org/10.1002/2017GL073660, 2017.

Credit: Michael Brady

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

National Aeronautics and Space Administration
Goddard Institute for Space Studies
New York, N.Y.

Aqua MODIS true color

June 17, 2015

Aqua MODIS true color

October 19, 2015

Himawari-8 true color
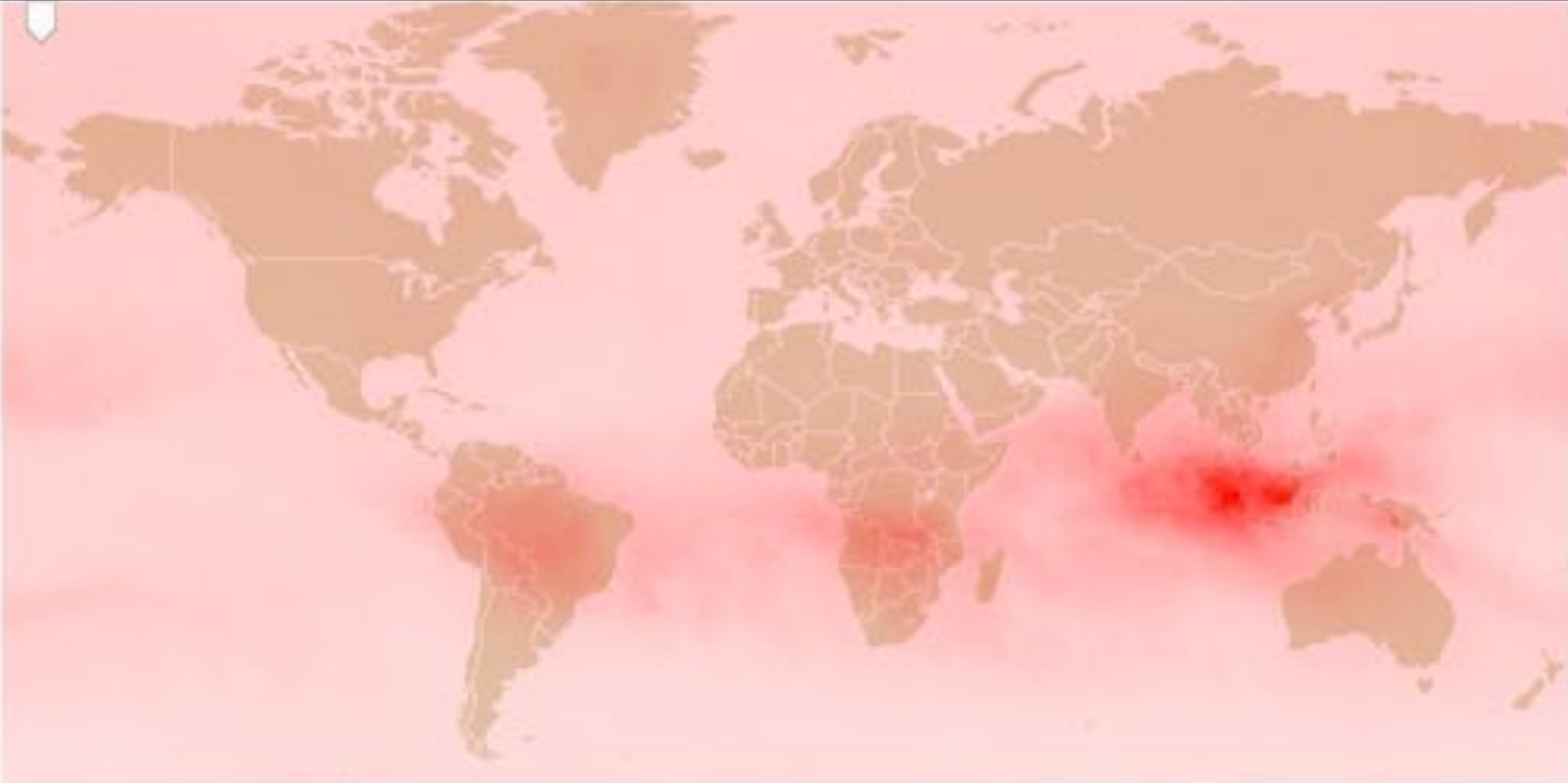## (Dan Lindsey, CSU)

July 3, 2015

October 20, 2015

Aqua AIRS Carbon Monoxide @ 500 hPa
October 13-26, 2015
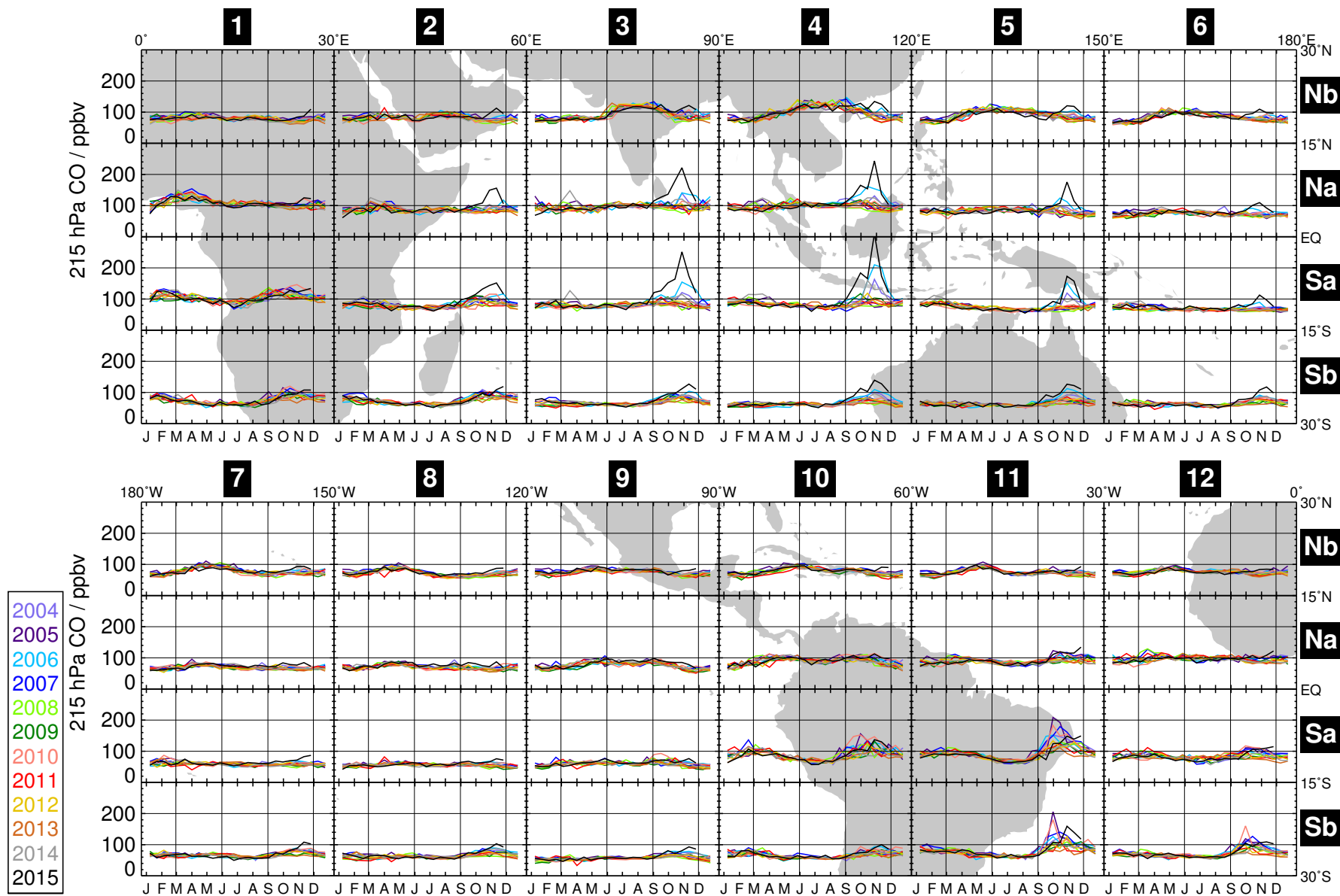

THE WALL STREET JOURNAL.

0 — 500 parts per billion by volume

Toggle zoom

Source: NASA's Atmospheric Infrared Sounder and Jet Propulsion Laboratory
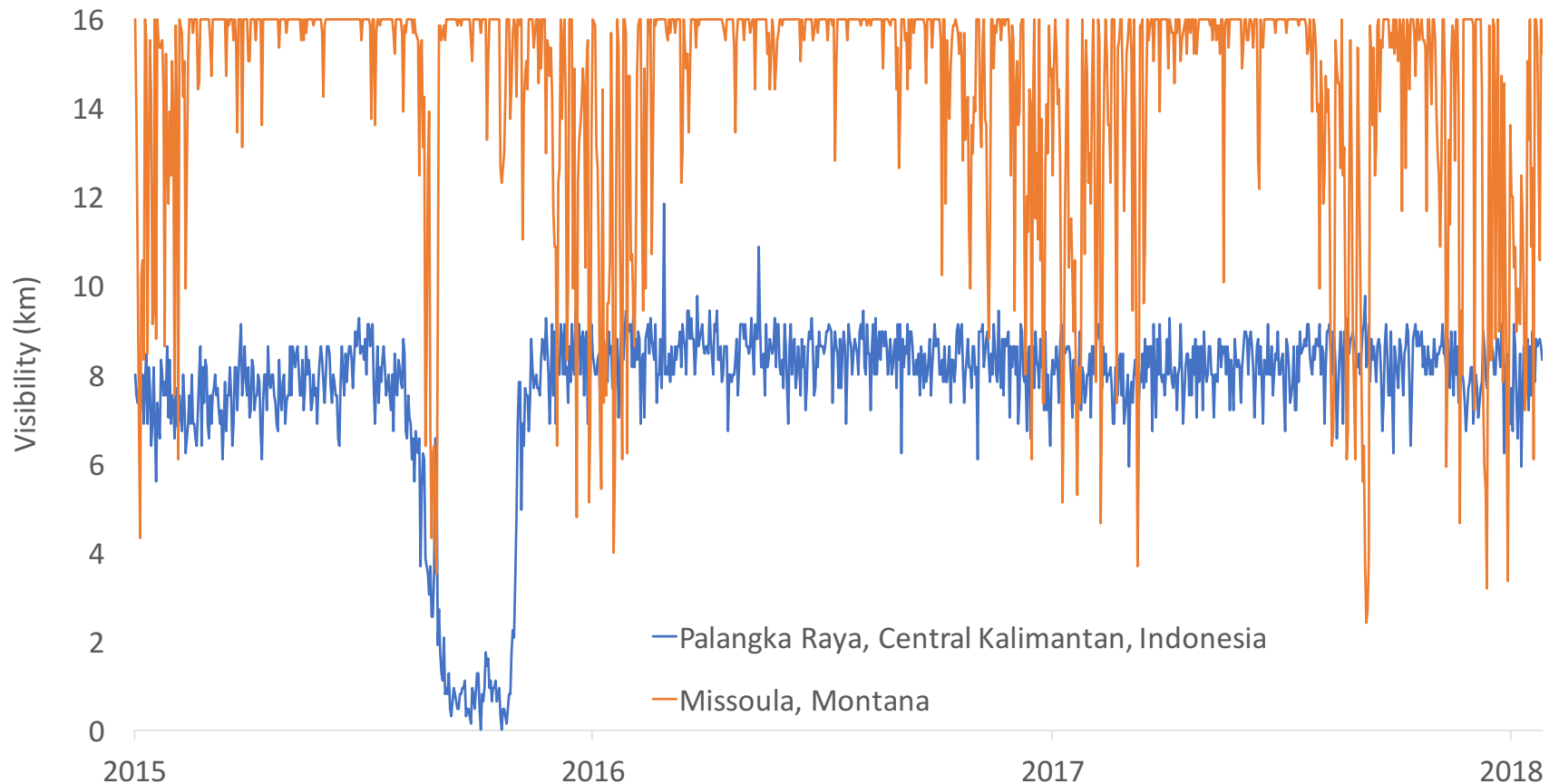
Aura MLS CO in the upper troposphere
(Nathaniel Livesey, JPL)

20 October PM$_{10}$ in Palangkaraya, Central Kalimantan (David Gaveau, CIFOR)

Airport visibility as an indicator of smoke

> 90% of emissions are from peat burning
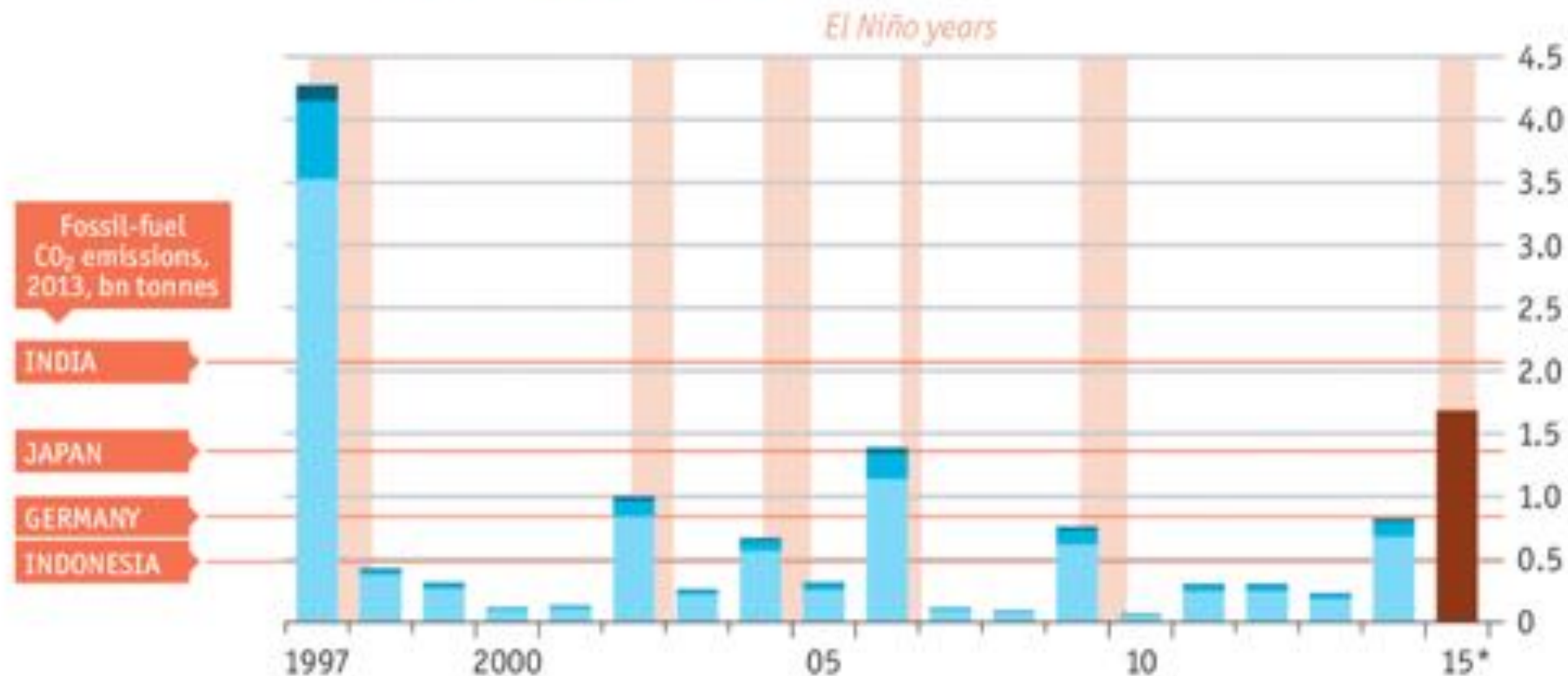(Levine et al., 1999, *GRL*; Page et al., 2002, *Nature*)

Katingan District, Central Kalimantan
Credit: Israr Albar

2015 was a repeat of past events

Emissions from Indonesian fires
Bn tonnes CO_2 equivalent from: CO_2 · CH_4 · N_2O

El Niño years

Fossil-fuel CO_2 emissions, 2013, bn tonnes
INDIA
JAPAN
GERMANY
INDONESIA

1997 · 2000 · 05 · 10 · 15*

Sources: Guido van der Werf; WRI; EDGAR

*To Nov 4th, total emissions

Economist.com

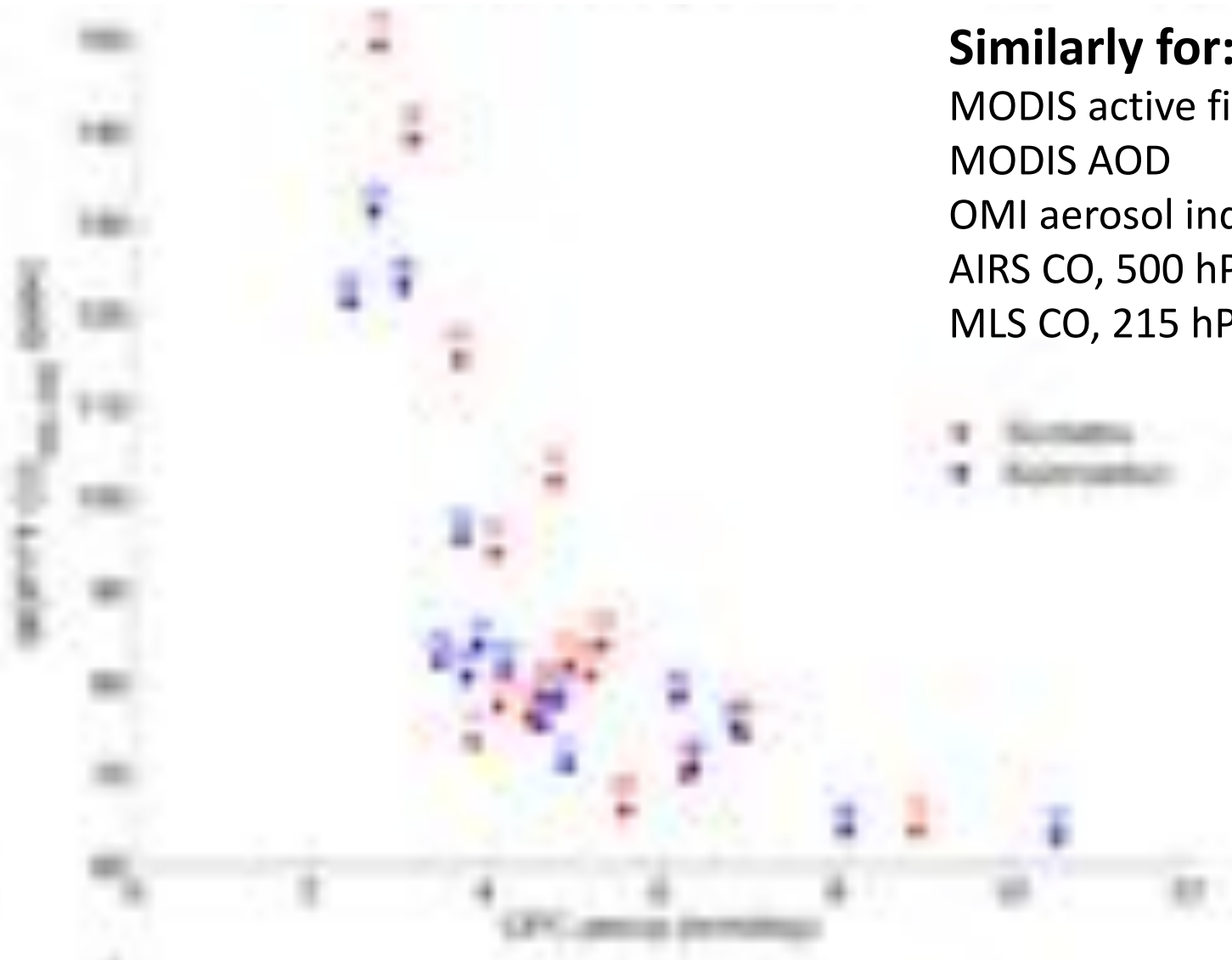# Seasonal precipitation is a strong control on fire and smoke

Similarly for:
MODIS active fires
MODIS AOD
OMI aerosol index
AIRS CO, 500 hPa
MLS CO, 215 hPa, 100 hPa
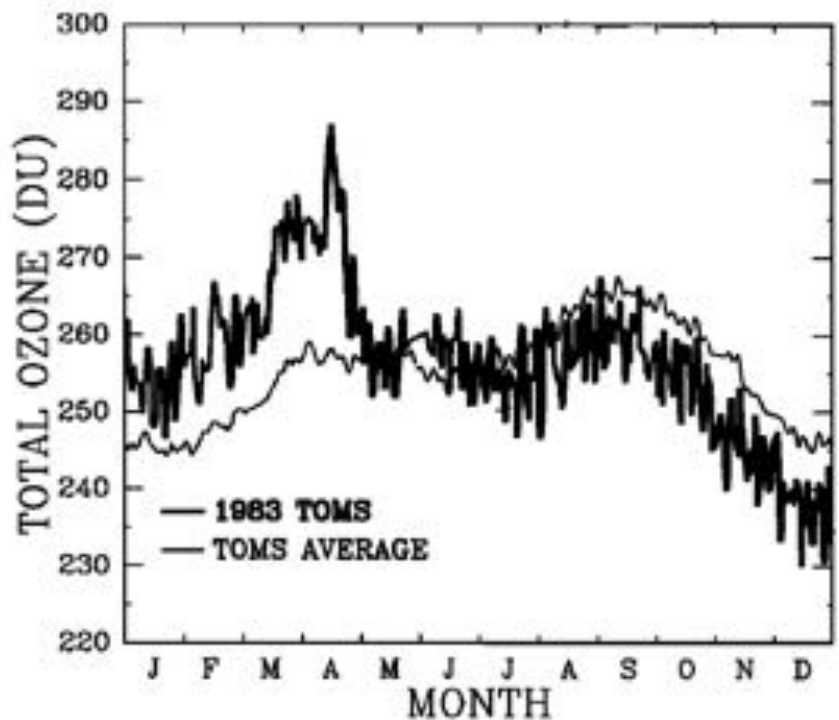
Field et al. (2016)

1983 fires in Borneo

The first (?) large-scale fires in Indonesia and Malaysia to be described quantitatively in the literature, and from space.
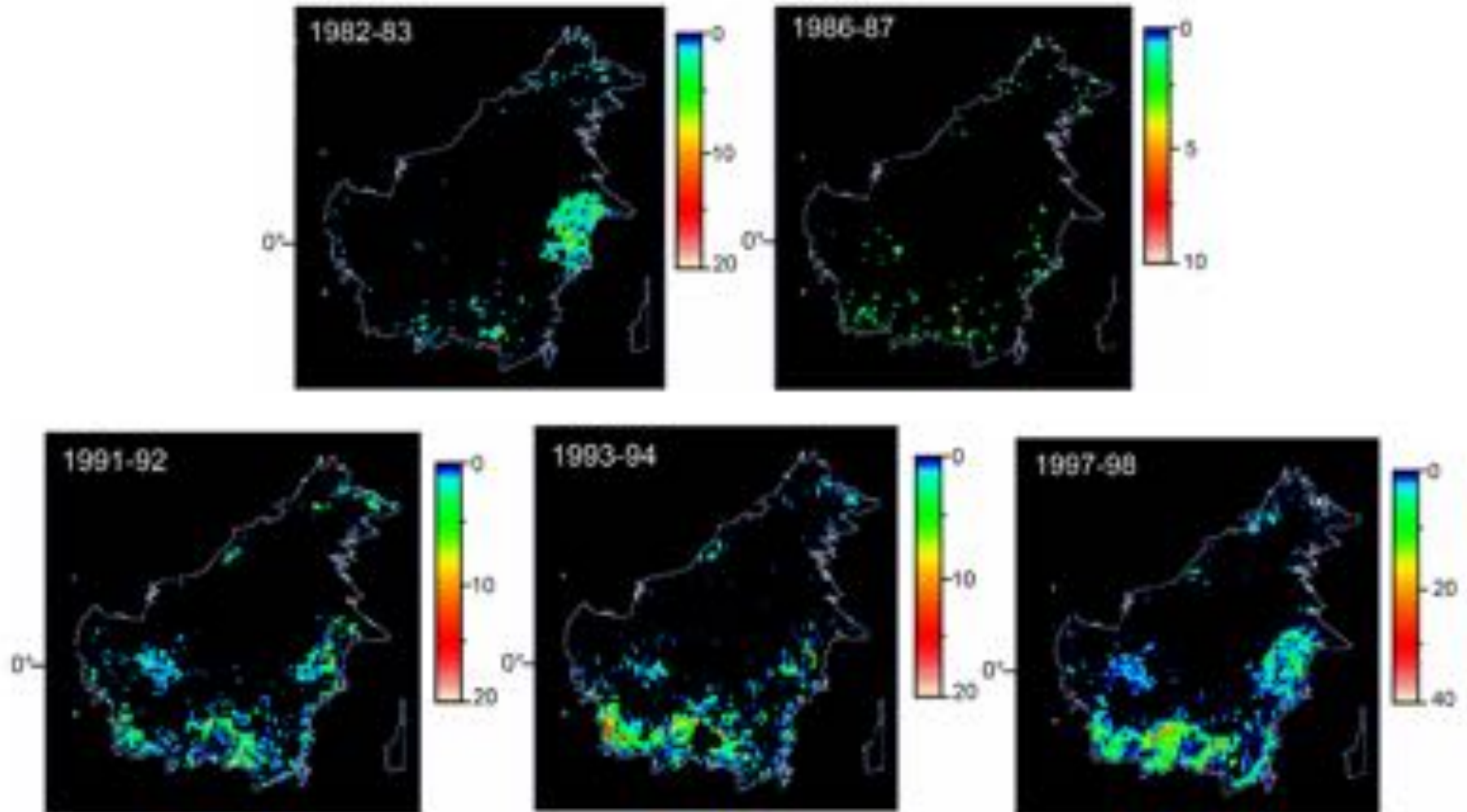

Malingreau et al. (1985, Ambio)
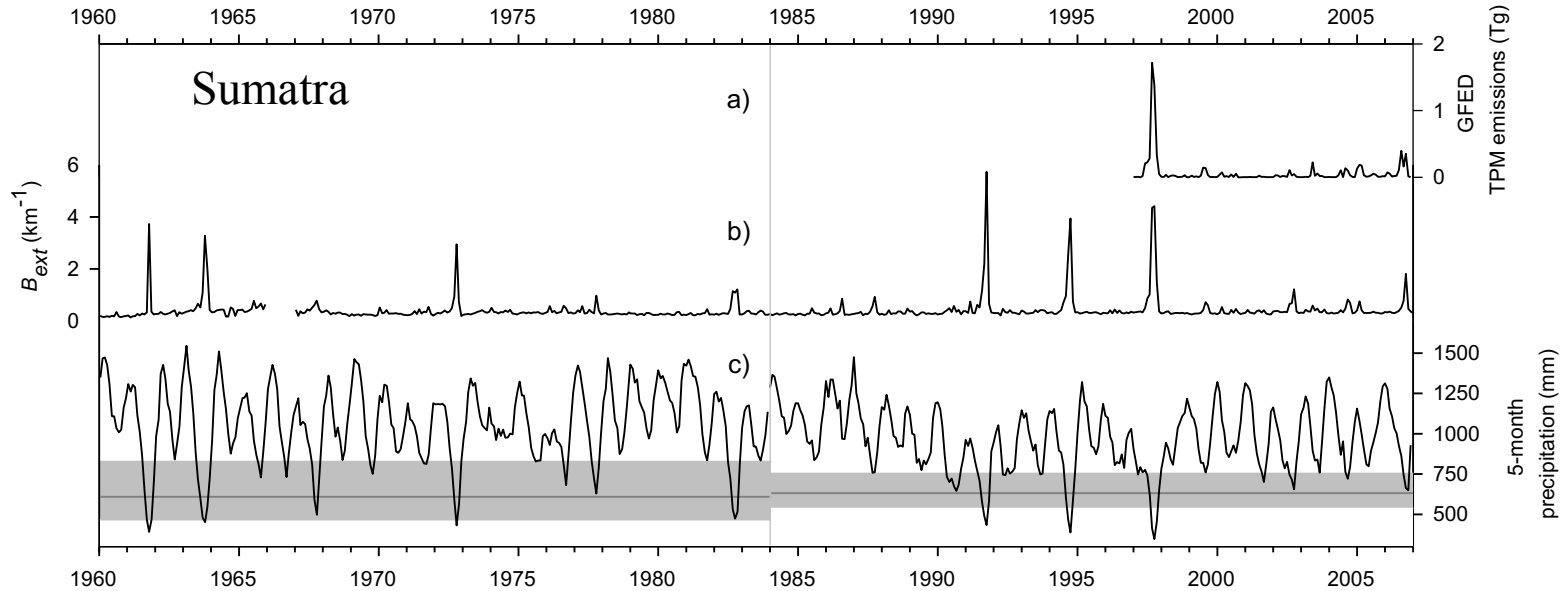(part of this work was carried out by L. Fellows, an intern at GISS at the time)
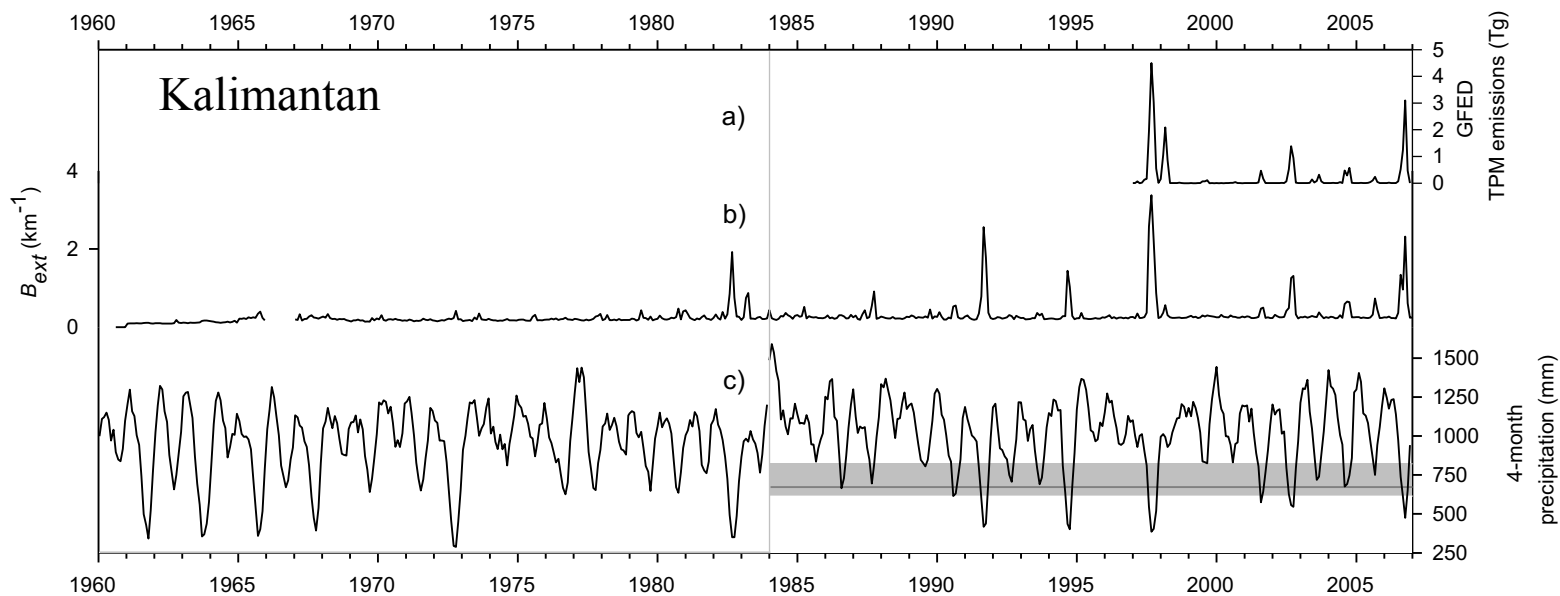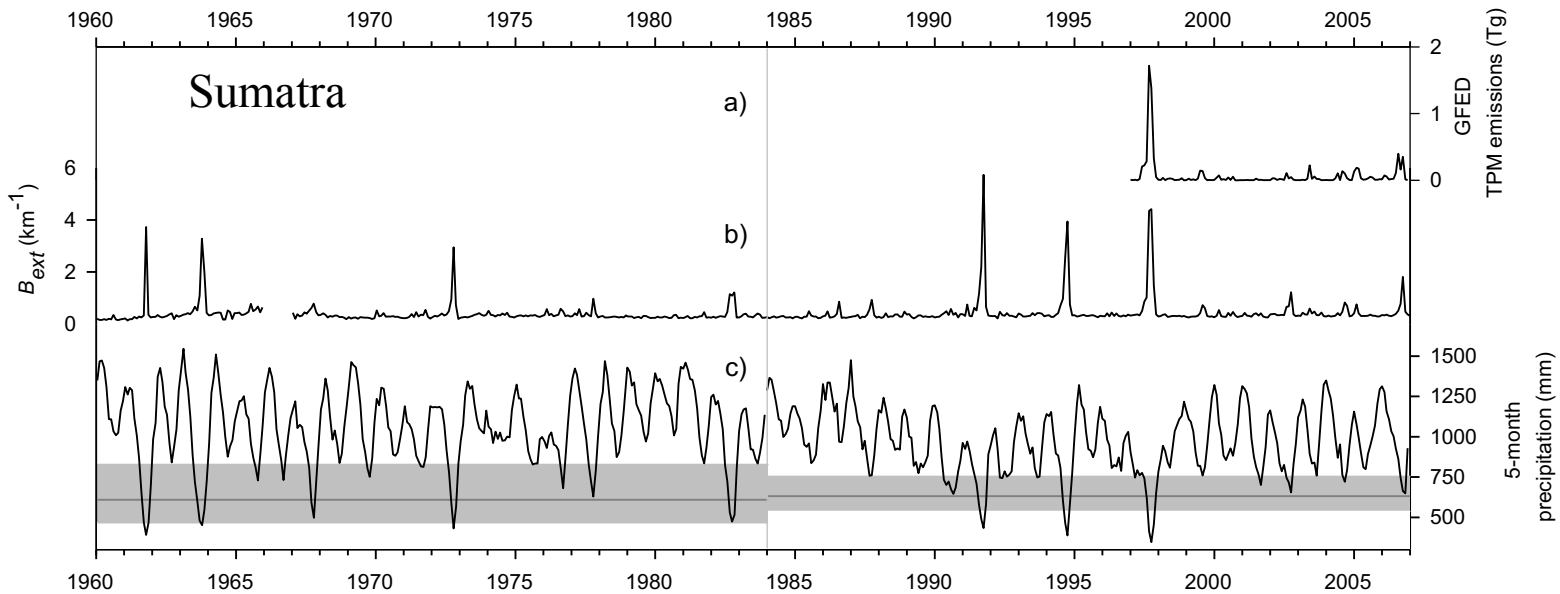
Fishman et al. (1990, JGR)

Persistent and expanding patterns of burning
Wooster et al. (2012, Biogeosciences)

Different fire histories in Sumatra and Kalimantan

Field et al. (2009)

Field et al. (2009)

1950 vegetation cover

Much of today's main burning region was previously undeveloped.

1956 surface transportation

Up-river shipping

Established overland transport networks

Coastal access only

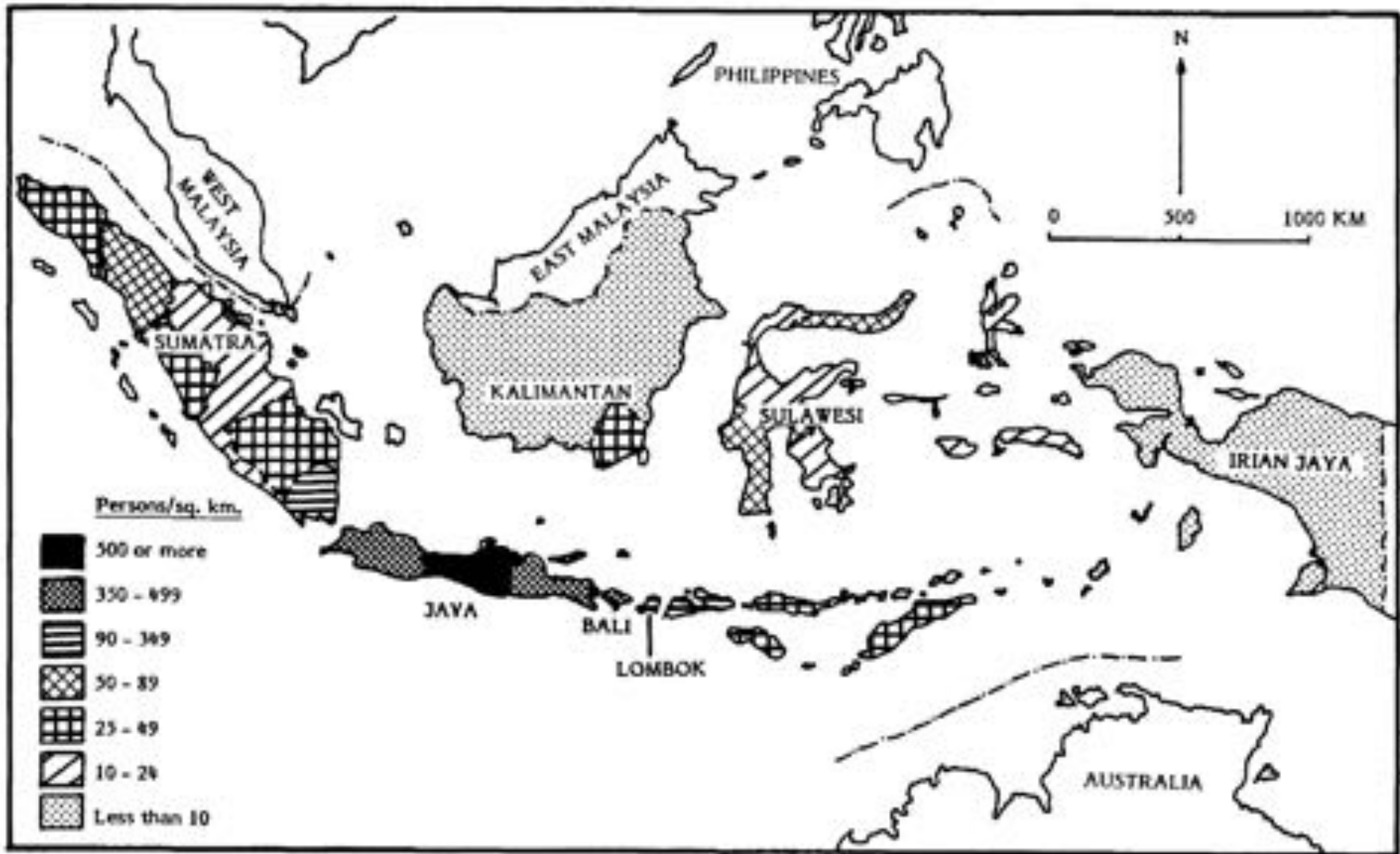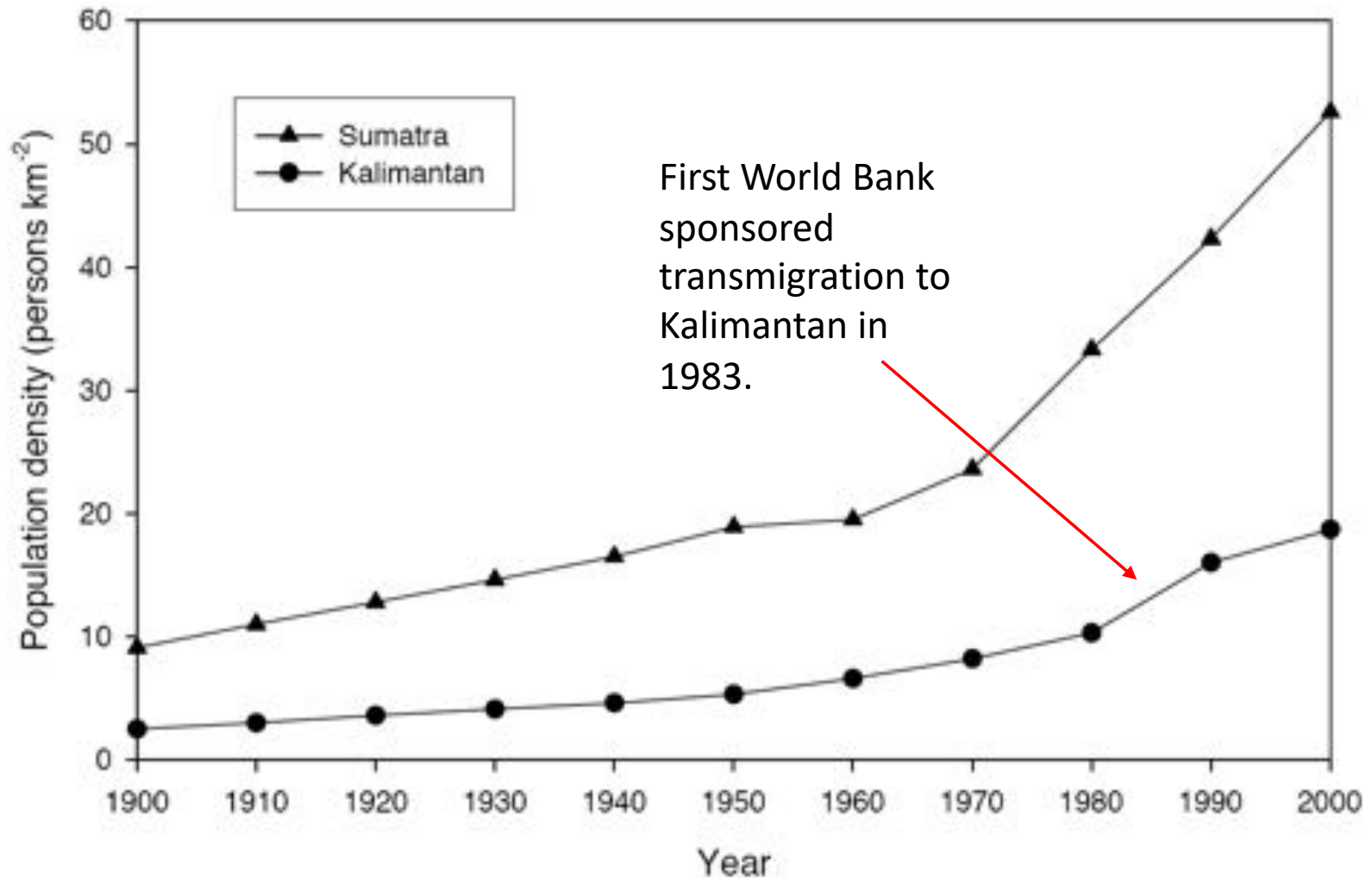Map: Netherlands Royal Tropical Institute

1976 rural population density

Fig. 1. Indonesia's rural population density in 1976 (Source: Hugo, 1980: 71).

And sparsely inhabited through the 1970s.
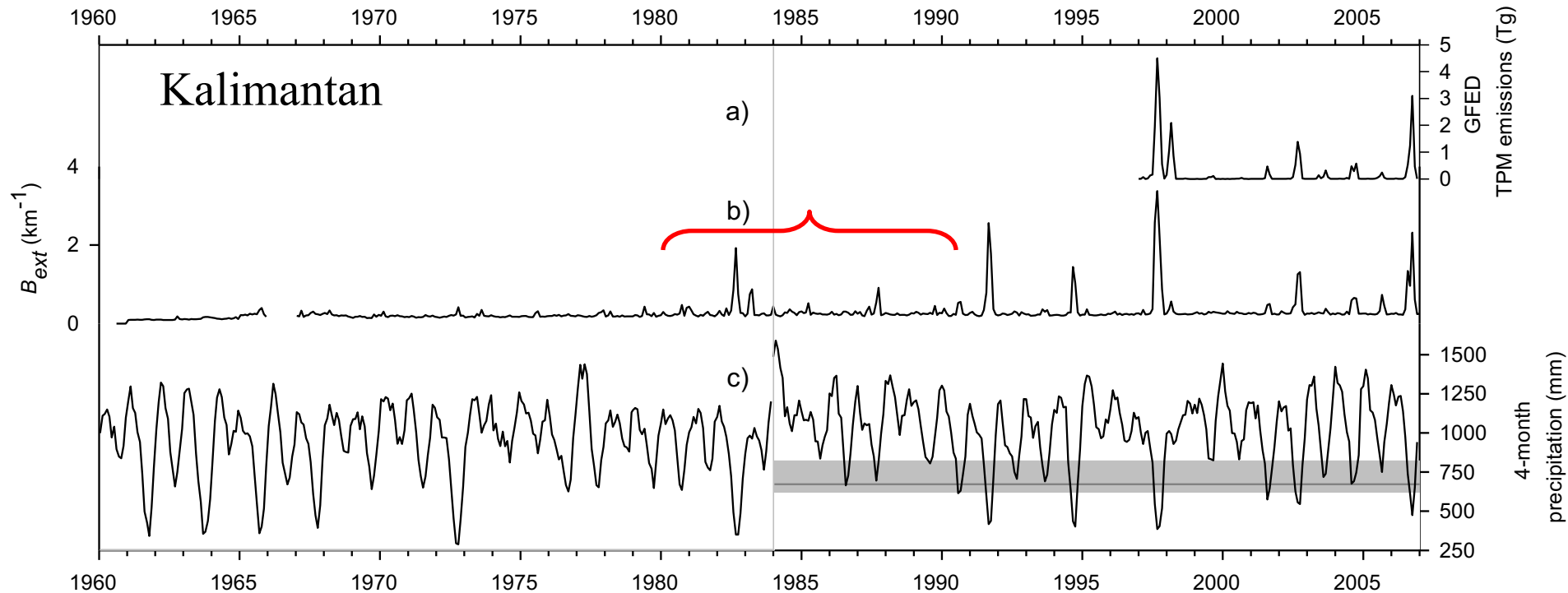
Population growth

First World Bank sponsored transmigration to Kalimantan in 1983.

Data: HYDE population database, Klein Goldewijk (2001, Glob. Biog. Cyc.)

In the 1980s, one of the world's great tropical forests became a singularly large source of pollution because of intensified land use.
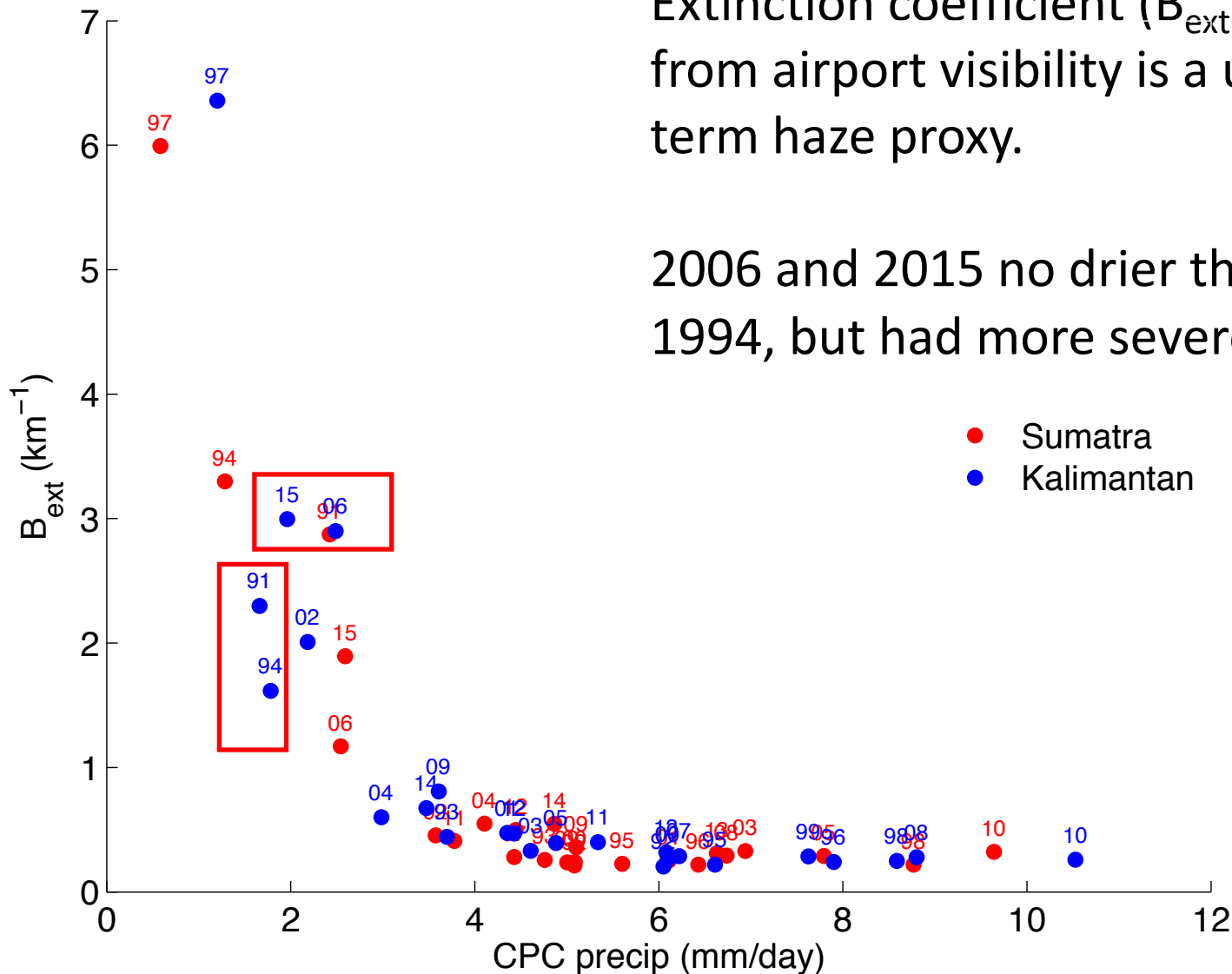

Field et al. (2009)

Fire sensitivity increasing over Kalimantan?

Extinction coefficient (B_{ext}) calculated from airport visibility is a useful long-term haze proxy.

2006 and 2015 no drier than 1991 or 1994, but had more severe haze.

Field et al. (2016)

There was a large-scale response in 2015 involving thousands of fire-fighters and international assistance.
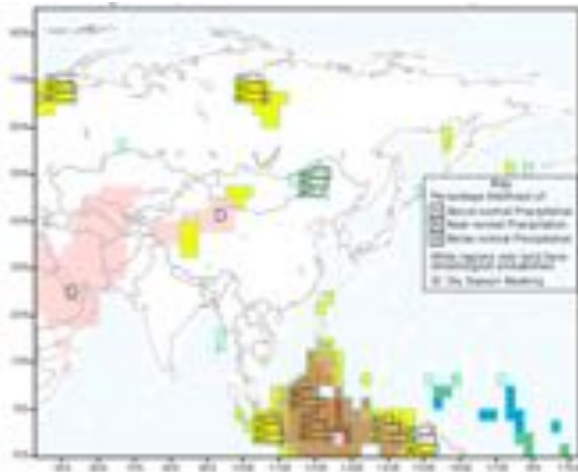
Credit: David Gaveau

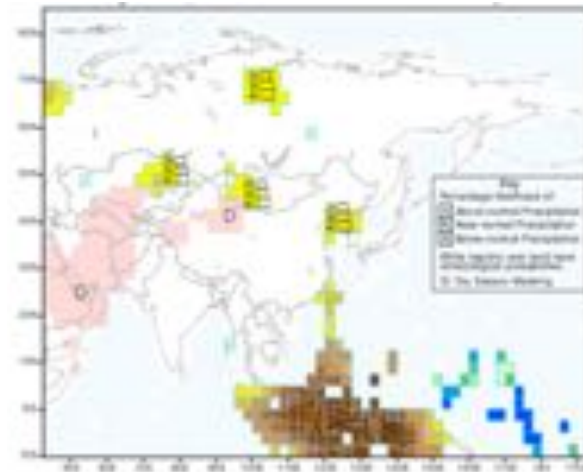# How far in advance could dangerously dry conditions have been anticipated, and what could have been done?
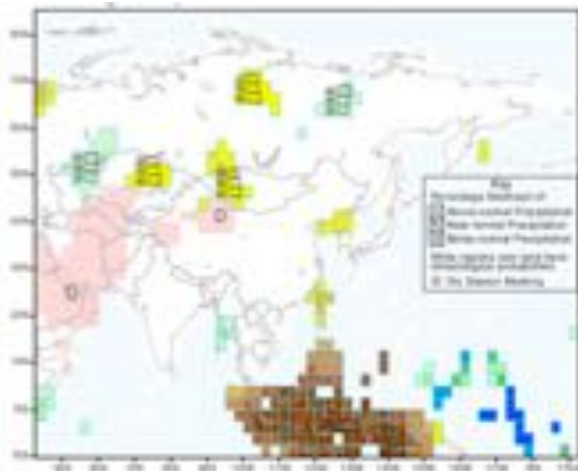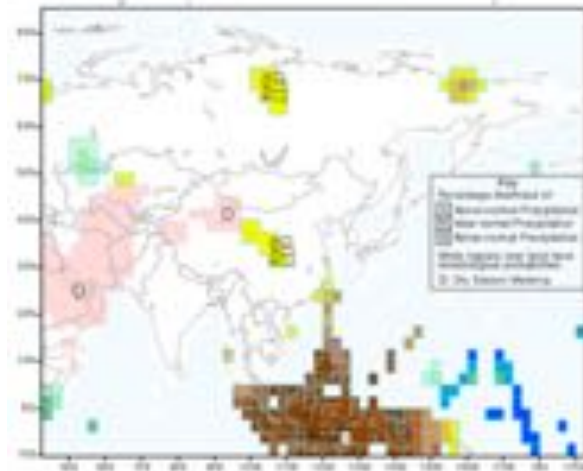
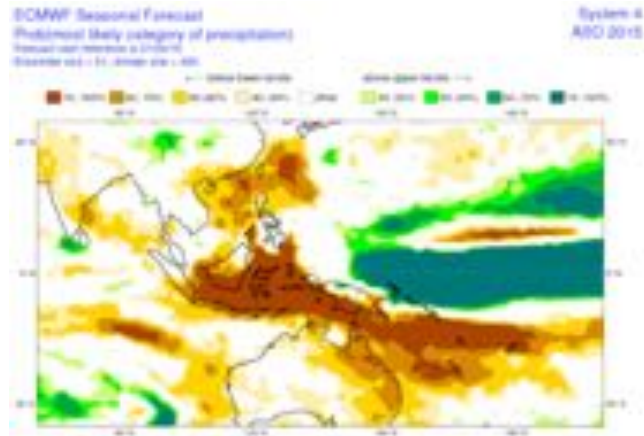# 2015 IRI Precipitation forecasts for ASO

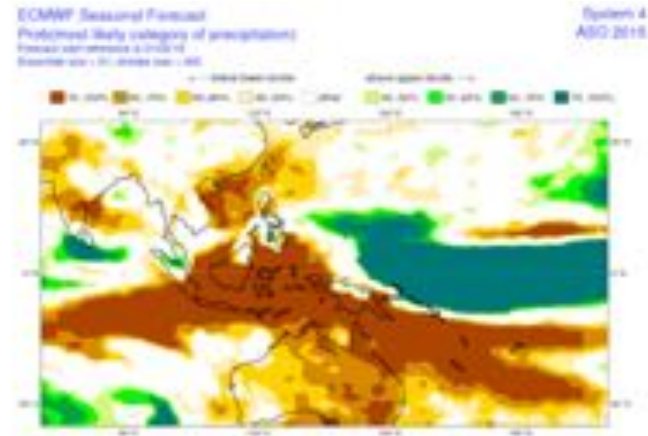
April

May

June

July

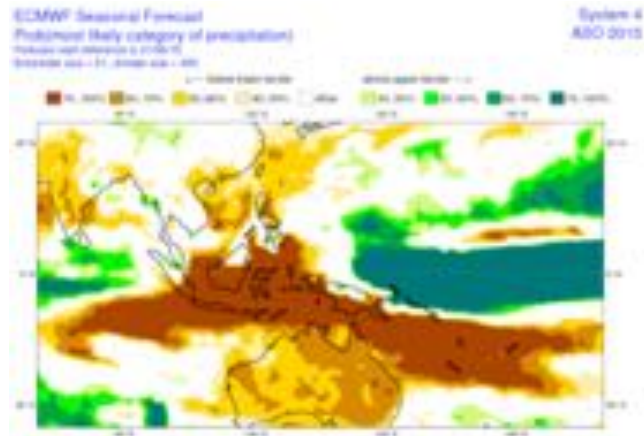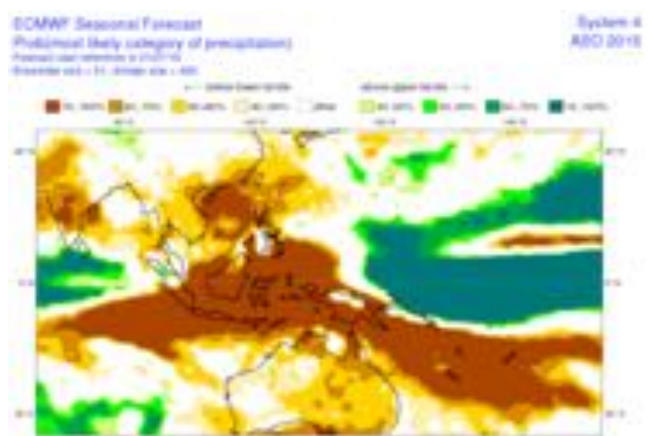# 2015 ECMWF Precipitation forecasts for ASO
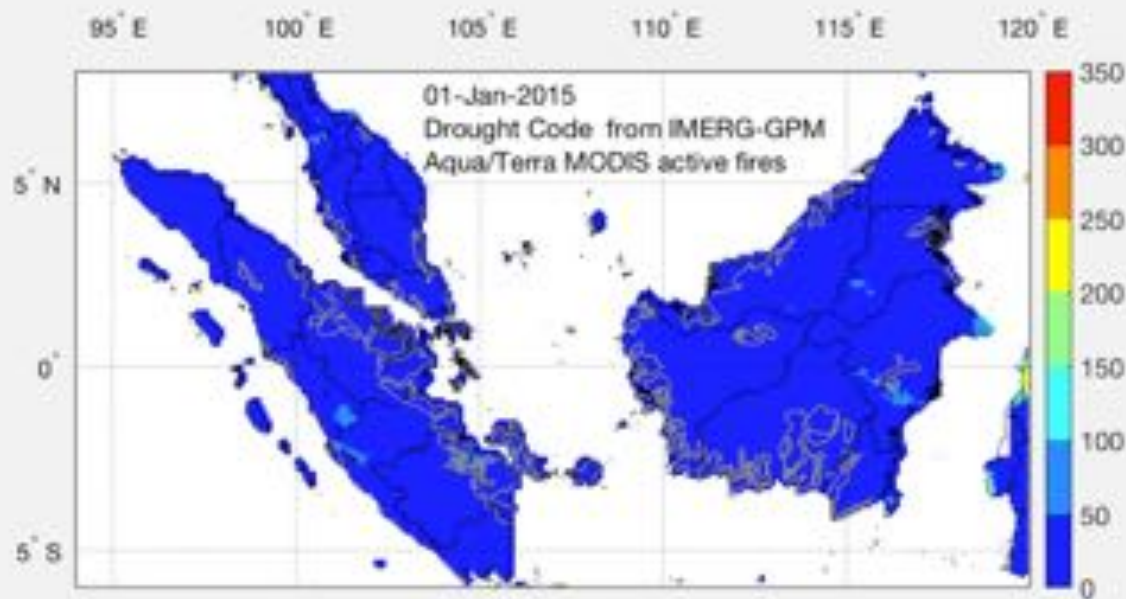
April

May

June

July

There is also a well-established Fire Danger Rating System

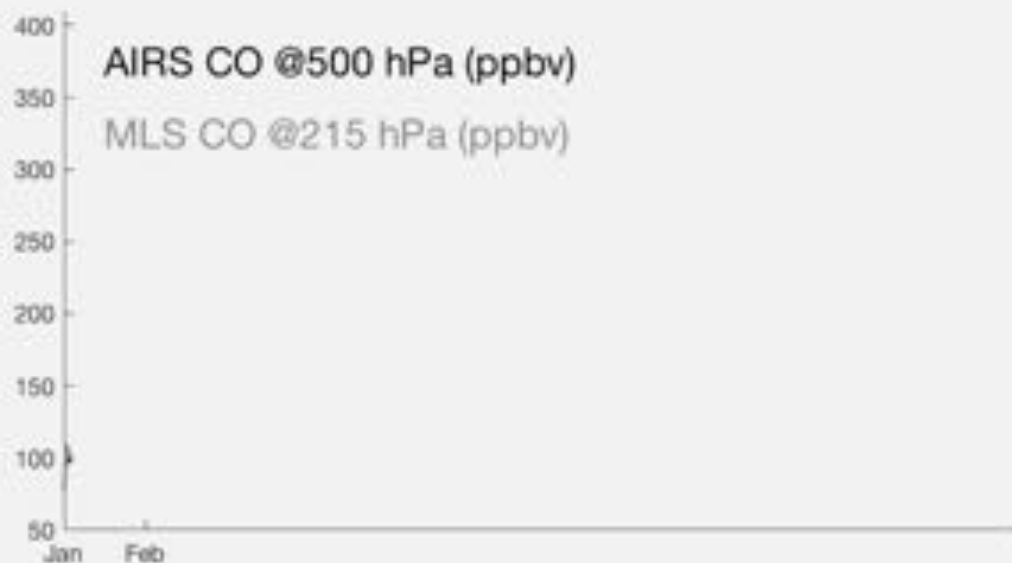The Drought Code is used in Indonesia as an indicator of peat fire potential.

DC > 350 considered extreme (de Groot et al., 2007, *Miti. Adap. Strat. Glob. Change.*)

The severe haze in September and October is from peat fires under extreme DC conditions.

01-Jan-2015
Drought Code from IMERG-GPM
Aqua/Terra MODIS active fires

http://data.giss.nasa.gov/impacts/gfwed/

AIRS CO @500 hPa (ppbv)
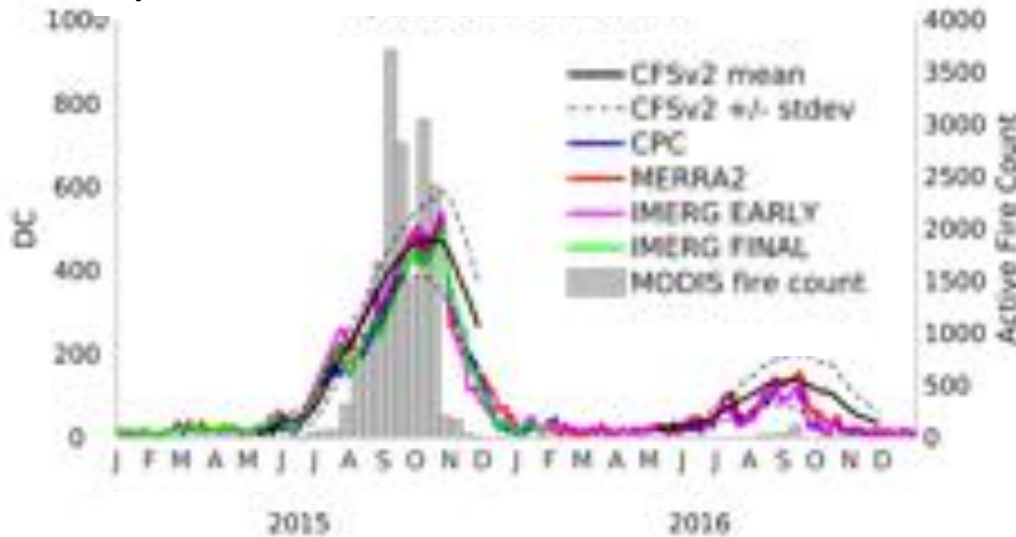MLS CO @215 hPa (ppbv)

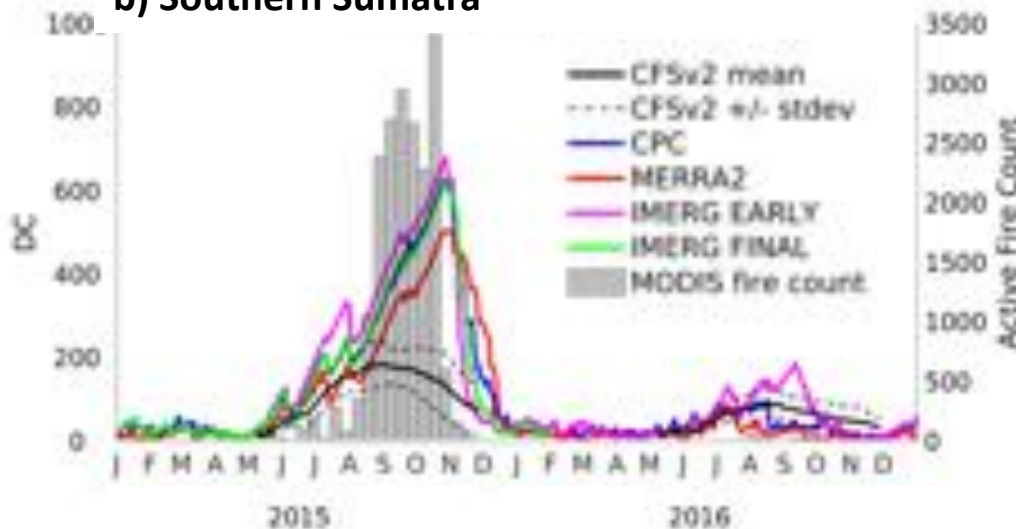# NCEP CFSv2 DC forecasts initialized in May
Shawki et al. (2017, GRL)

a) Southern Kalimantan

Over Kalimantan, the May forecast accurately predicted high DC in September and October.

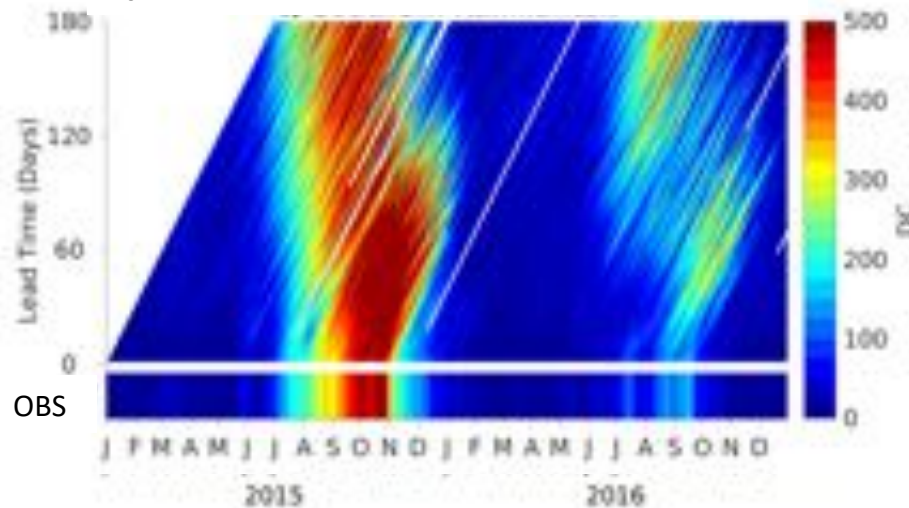**b) Southern Sumatra**

Over Sumatra, the May forecast missed the high DC entirely.

DC forecasts at different lead times

a) Southern Kalimantan

Over Kalimantan, 2015 forecasts were consistently good with 6-month lead times, but did predict too-long drought at lead times greater than two weeks.

b) Southern Sumatra
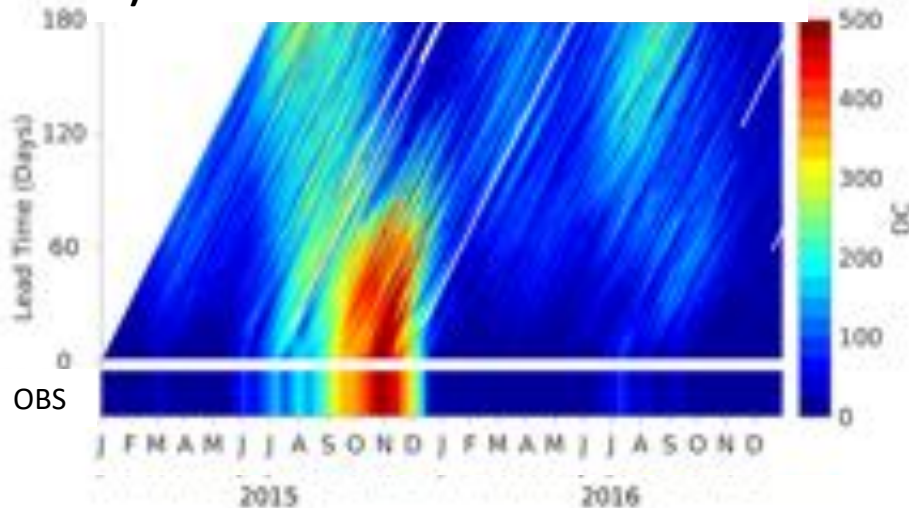
Over Sumatra, the forecasts became accurate with a 2-month lead time.

Dry conditions over Sumatra are associated with positive Indian Ocean Dipole conditions – a decrease in SSTs from west to east – more strongly than Kalimantan.

This gradient was not well-forecast in May.
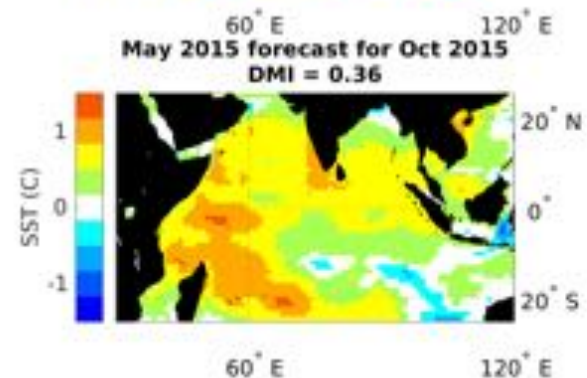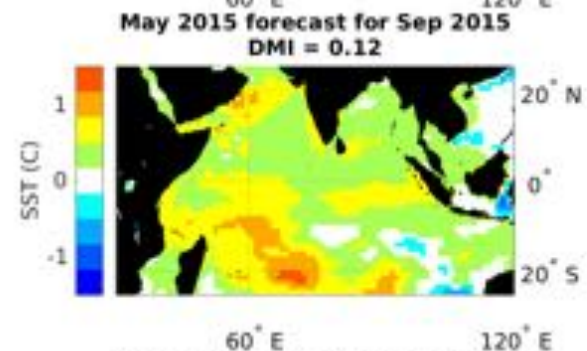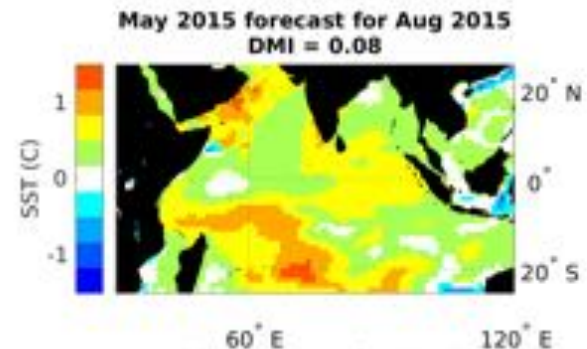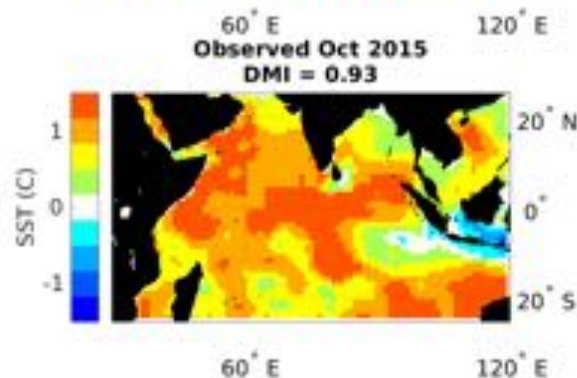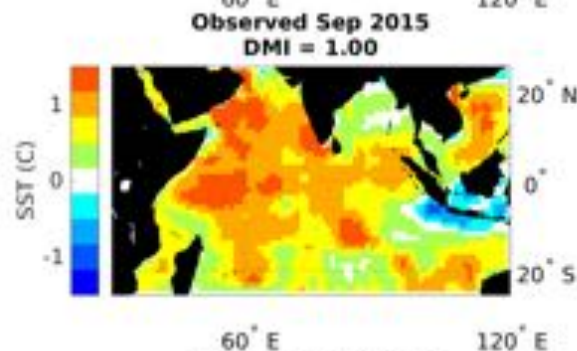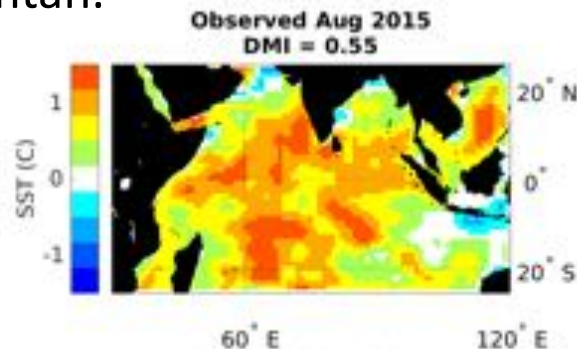
2017 forecast

Over Kalimantan, 2017 forecasts through May were driven by predictions of an El Niño, which did not verify.
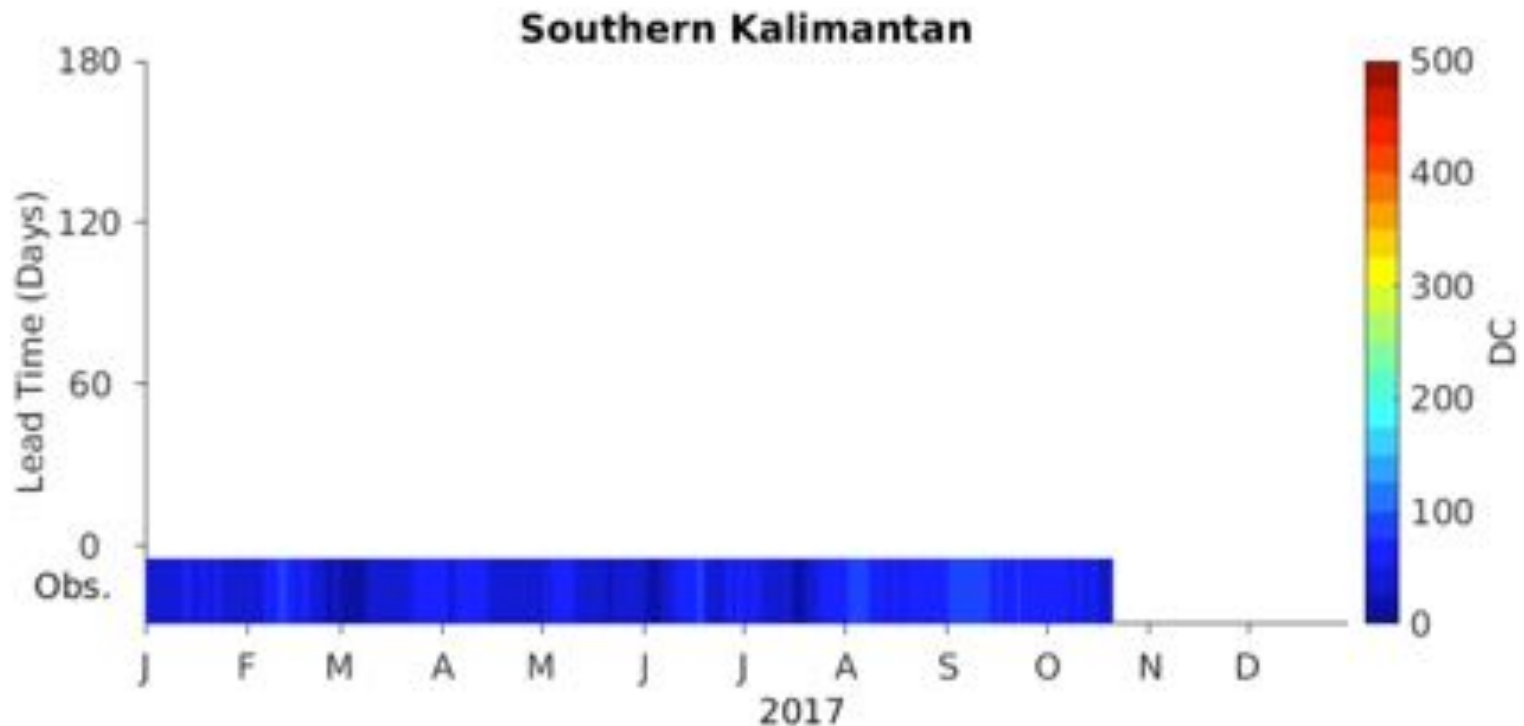
1982-2010 precip skill over all of Indonesia
Setiawan et al. (2017, Int. J. Clim.)

Monthly model / obs. precip anomaly correlation for increasing lead times, NCEP CFS v2.

Indonesian Prec Anomaly Correlation of CFSv2 and GPCC
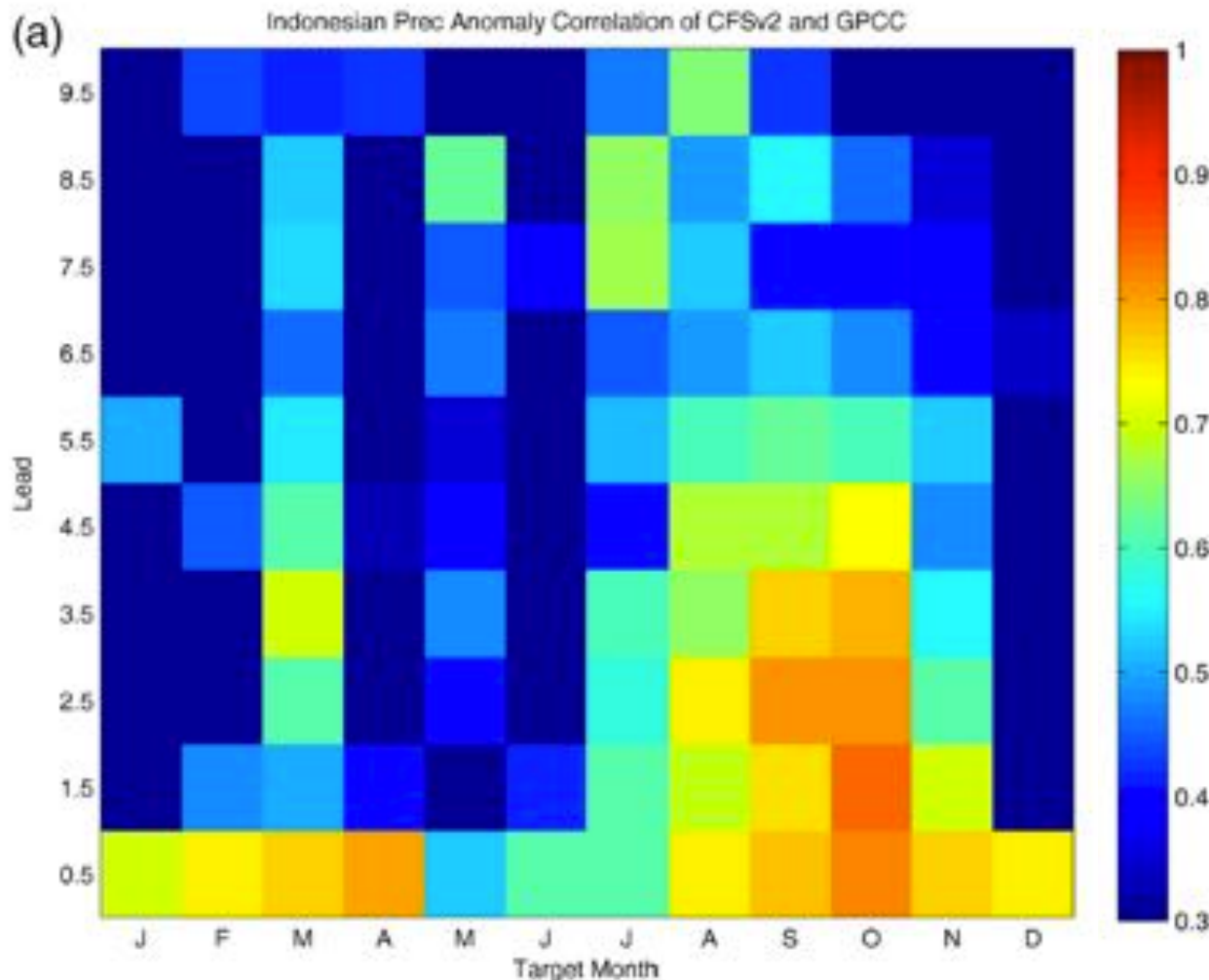
Skill varies across NMME models
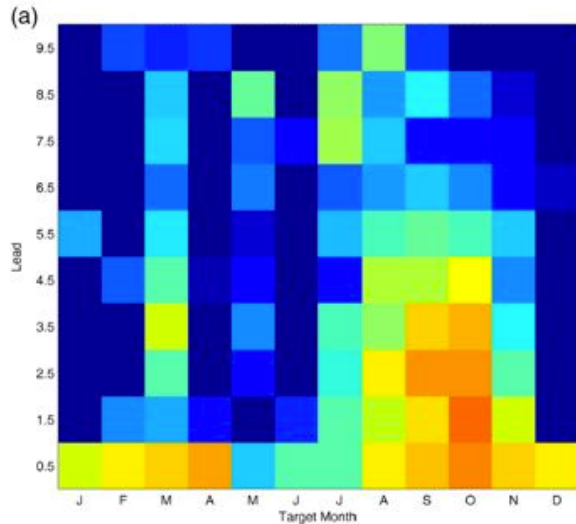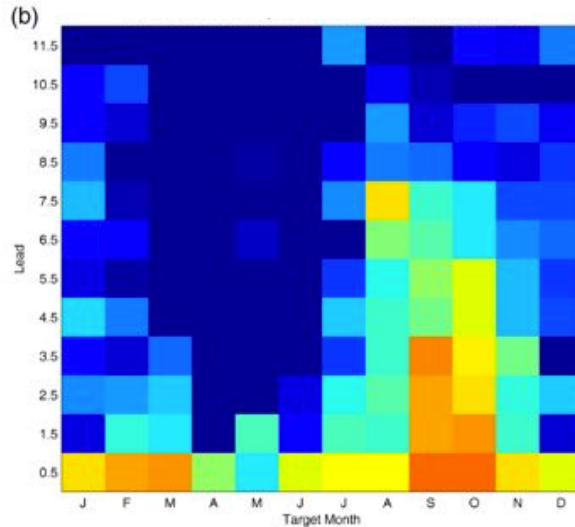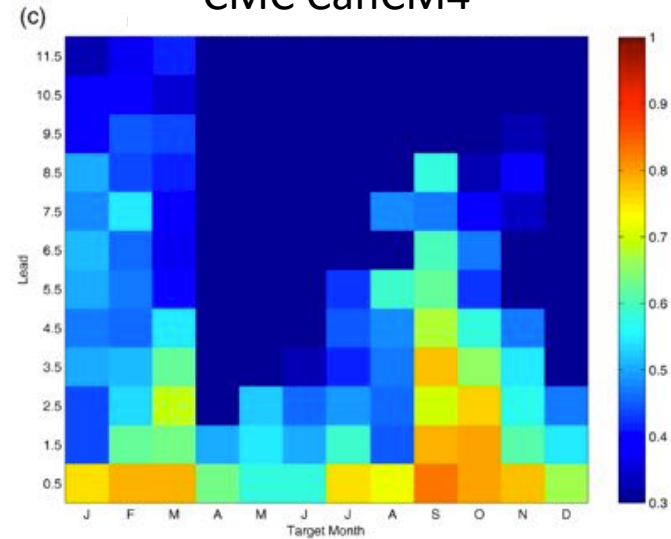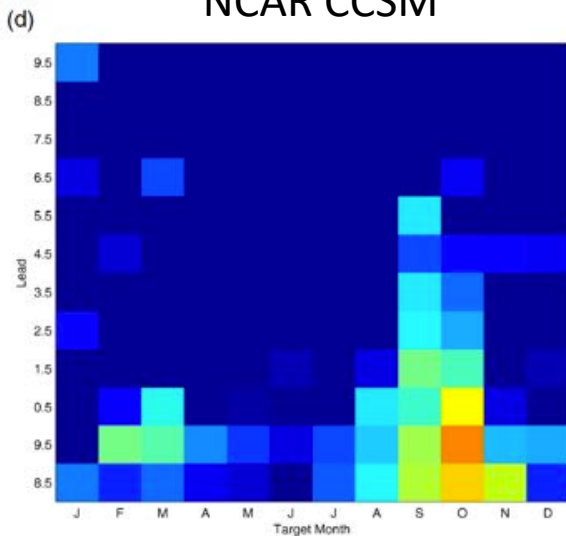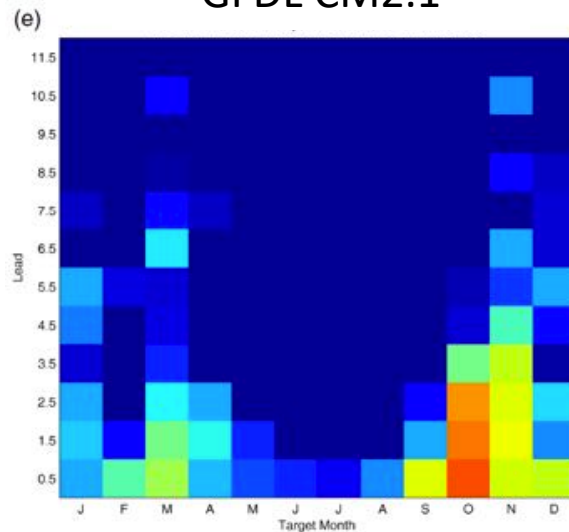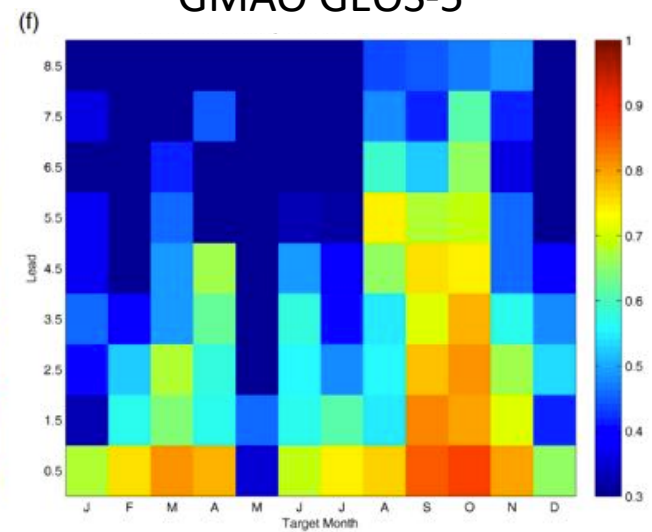
June-September sub-seasonal precipitation skill

(Li and Robertson, 2015, MWR)
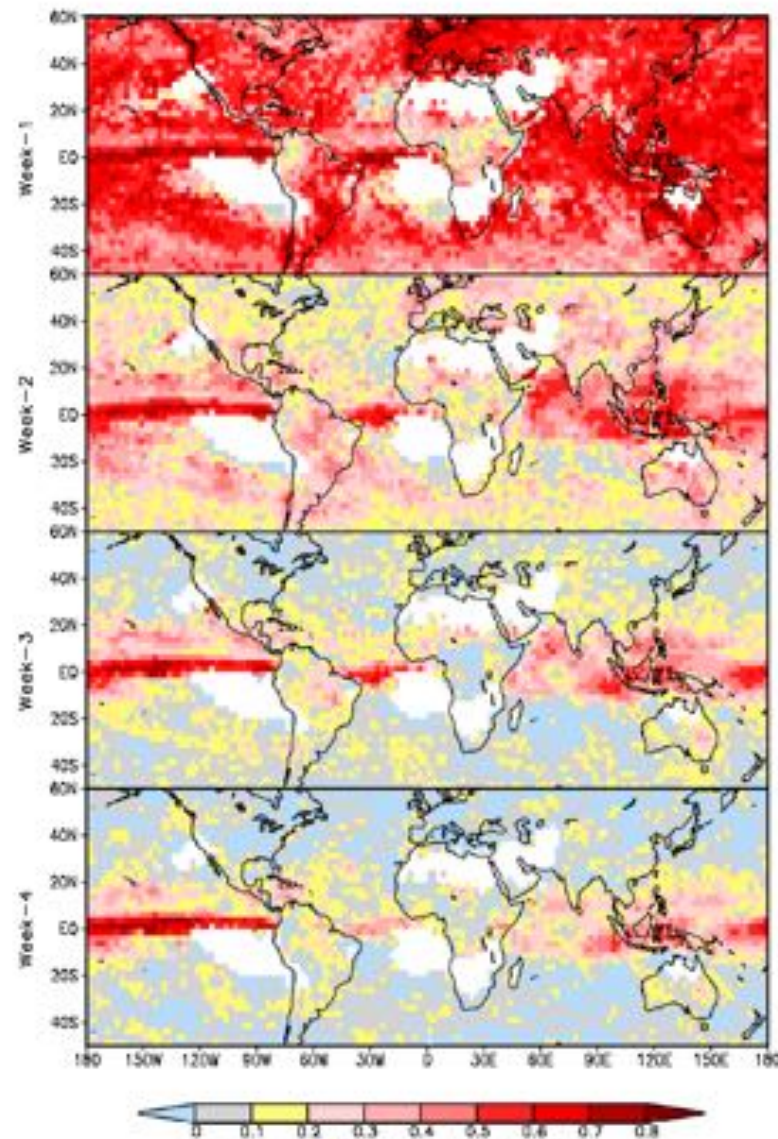
FIG. 3. As in Fig. 1, but for the ECMWF hindcast.

Decision aid development – Prevention (c/o Israr Albar, MoEF)

❑ Public education through campaign, socialization, advertisement, exhibition, social media on land and forest fire control (poster, leaflet, neon box in airport, media outreach, advertising, national scout camp)

❑ Governor instruction on land and Forest Fire Prevention in Jambi, west Kalimantan, south Kalimantan, and South Sumatera.

❑ Declaration of Provincial Police Chief on Burning Prohibition

Decision aid development – Suppression

SUMATERA	
South Sumatera	180
Riau	210
Riau Islands	30
Jambi	285
South Sumatera	240

KALIMANTAN	
West Kalimantan	315
Central Kalimantan	270
South Kalimantan	180
East Kalimantan	90

SULAWESI	
North Sulawesi	30
South east Sulawesi	30
South Sulawesi	120

**Manggala Agni
1.980 personel
37 Forest Fire Station in
12 fire prone provinces**

1. **MANGGALA AGNI (MA) Forest and Land Fire Brigade (MoEF)- 1980 personel, 37 station, 12 fire prone province**
2. **Army and Police**
3. **BNPB**
4. **Forest Fire Brigade on Forestry and Plantation industry**
5. **Fire Care Community (MPA) -9963 pers, 26 province**

Conceptual forecast-based decision aid

Chance of catastrophic fire danger in 2 months	Monitoring	Prevention	Suppression	Mitigation
< 25%	Monthly updating of BMKG medium-range forecasts.	BMKG, KLHK routine posting of forecasts indicating an inactive fire and haze year.	Reciprocal offers of assistance to other fire-affected countries.	Conduct routine, interagency 'table-top' mitigation exercises.

Chance of catastrophic fire danger in 2 months	Monitoring	Prevention	Suppression	Mitigation
25-50%	Bi-weekly updating of BMKG medium-range forecasts.	Public notification of 'normal' fire year.	Increase frequency of KLHK 'Manggala Agni' fire-fighter training.	Alert health agencies to likelihood of 'normal' fire year.

Chance of catastrophic fire danger in 2 months	Monitoring	Prevention	Suppression	Mitigation
50-75%	Weekly updating of BMKG medium-range forecasts. Begin KLHK, BRG monitoring of water table levels in degraded peat.	Public warnings of possibility of above average fire year. Weekly inspection of canal-blocking dams in degraded peat.	Mobilization of reserve fire-fighters from Fire Care Community Volunteers. Notification to international partners of possible need for assistance.	Alert public health agencies to possibility of above average fire year.

Chance of catastrophic fire danger in 2 months	Monitoring	Prevention	Suppression	Mitigation
> 75%	Twice-weekly updating of BMKG medium-range fire danger forecasts. Daily monitoring of BMKG and LAPAN fire activity, haze, and atmospheric transport patterns.	Full-scale media campaigns and Integrated Prevention Patrol deployment. Early declaration of states of emergency as necessary, and provincial-level transfer of authority to BNPB. Release of emergency 'fire disincentivization' funds.	Pre-positioning of suppression resources in areas of highest expected fire activity. Requests for international fire-fighting assistance.	Clean air shelter pre-positioning in vulnerable airsheds. Pre-positioning of buses and navy ships in vulnerable airsheds, possible early evacuation.

Proposed skill evaluation and application

- Refine critical fire danger thresholds over Indonesia using EOS-era data

- Compute 30-year seasonal fire danger hindcasts over Indonesia using NCEP CFSv2, GEOS-5, ECMWF

- See how well the models do in predicting dangerously dry conditions at seasonal, sub-seasonal and synoptic scales

- Operationalize fire danger forecasts at Indonesian Met Service

- Incorporate seasonal forecast products into decision aids at Ministry of Environment and Forestry, Board for Disaster Management